Physics Division Overview

Jim Siegrist

Director's Annual Review

November 10-11, 2004

A Center of Excellence for the HEP Community

- *Physics Ideas from LBNL*
  - Asymmetric B Factory to probe CP violation in quark sector
  - Supernovae to measure the acceleration of the Universe
- *Innovation at LBNL*
  - Time Projection Chamber (TPC)
  - ASICs for silicon vertex detectors and pixel detectors
  - CCDs for space and ground-based astronomy
  - Analog Transient Waveform Digtiizer for non-Accelerator experiments
- *Instrumentation developed at LBNL*
  - BaBar: Silicon Vertex Tracker, Cerenkov Ring Detector, Trigger
  - CDF: Central Outer Tracker, Run II silicon
  - ATLAS: silicon strip modules and pixel detectors

Creativity, Ingenuity & Technical Capability

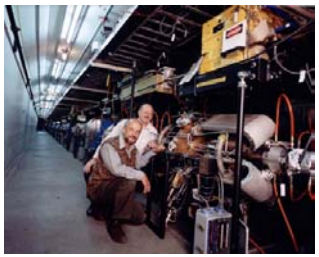
Infrastructure is Highly Leveraged

- Outstanding faculty supported by UC Berkeley
- Small but dedicated full-time scientific staff
- Excellent technical resources
  - Computing Division (NERSC)
  - Engineering Division (e.g. IC design)
  - Large machine shops, clean room facilities
- Direct support from the lab via LDRD
- Synergy with Nuclear Science and Accelerator Divisions

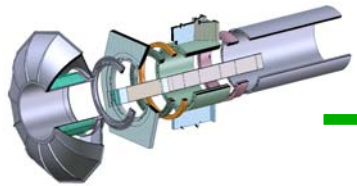
LBNL Contributions Enhance University Collaborations

- **LBNL collaborates closely with the University community:**
  - ✓ **Shared equipment and infrastructure for chip design, silicon detector systems**
  - ✓ **Engineering expertise in advanced electronics, instrumentation and mechanical design**
  - ✓ **Integration of theory with experiment**
  - ✓ **Computing expertise and operations support from NERSC**

Doing the Physics from Start to Finish (Example: BaBar)



Conception

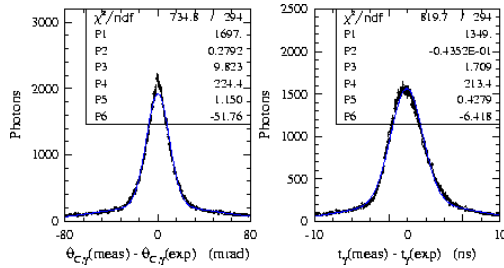


Design

BaBar team - LBNL
XBD9902-00245-07

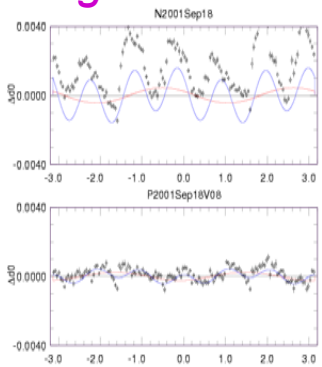
Fabrication

DIRC



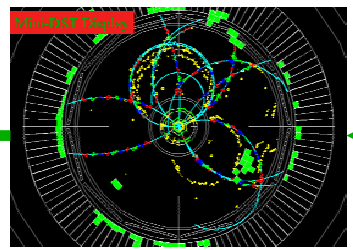
Commissioning

Alignment

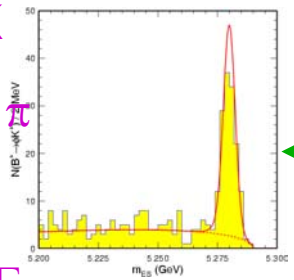


Operations/
Calibration

Trigger



Reco/
Simulation



Analysis

New computing model

SVT upgrade

B→VV

B→φ K

B→Ds π̄

B→ρπ

CPT,ΔΓ

Physics Division Program is Designed To Address the Fundamental Questions

- **Origin of Mass & Electroweak Symmetry Breaking**
  - *CDF, ATLAS, LC*
- **Dark Energy & Dark Matter**
  - *SNAP, SNF, SCP, CMB*
- **Matter/Antimatter: masses & CP phases**
  - *Quarks: BaBar, CDF*
  - *Neutrinos: KamLAND, ICE^3(NSD), θ_{13}*

Program Overview

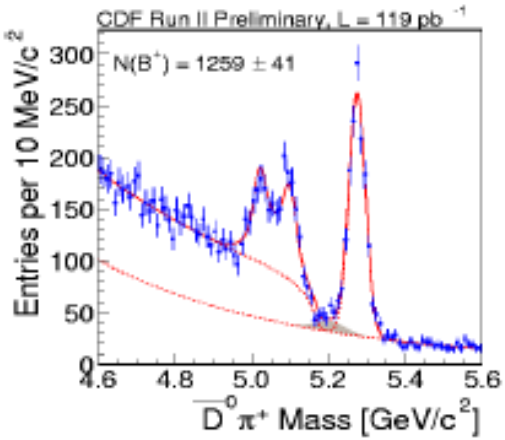
- **Accelerator Experiments**
  - Present: BaBar, CDF
  - Imminent: ATLAS
  - R&D: LC
- **Non-Accelerator Experiments**
  - Present: KamLAND, SCP/SNF
  - R&D: SNAP, APEX-SZ, South Pole Telescope
  - Incubating: θ_{13} at a reactor, CMB polarization
- **Community Service**
  - PDG, Quarknet, Leadership

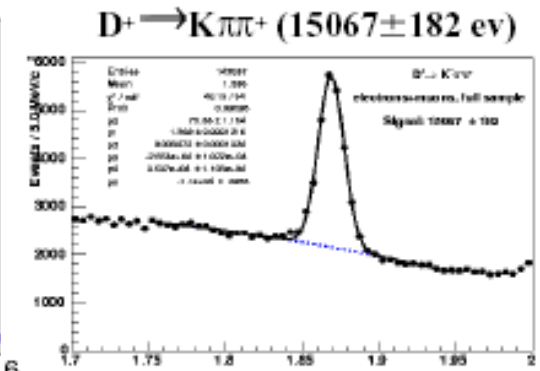
SNAP (Dark Energy) and ATLAS (EWSB) are our highest priorities

Present Program

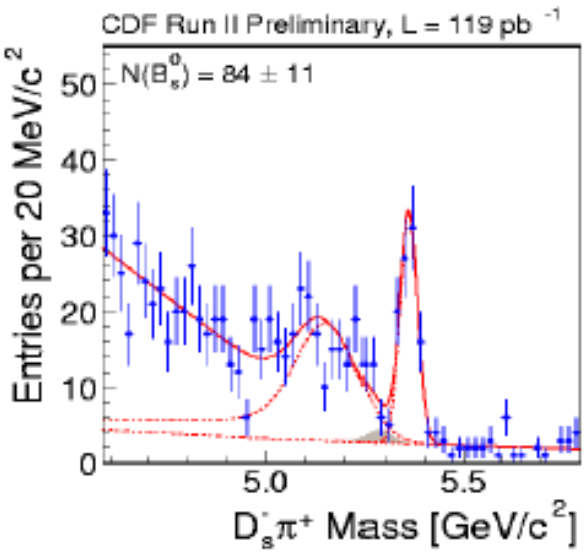
LBNL Role in CDF Physics Program

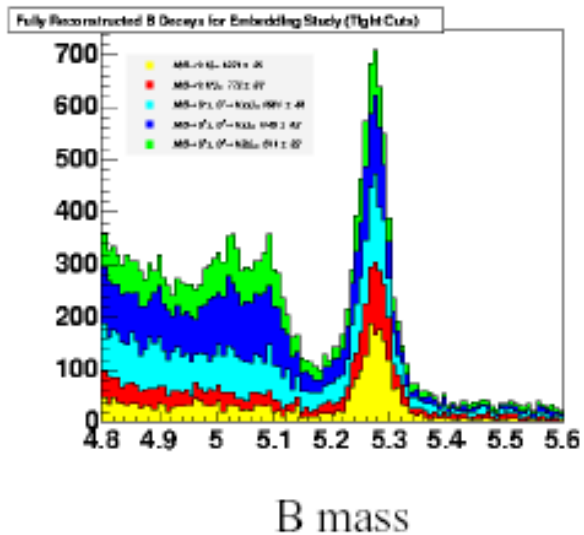
- **Leadership**
  1. **Four subgroup convenors**
     - *Jet Corrections*
     - *Higgs*
     - *B Tagging*
     - *Semileptonic B*
  2. **Convenor:**
     B Physics Group M.Shapiro





- **B Physics**
  - **B_s Mixing**
  - **V_{cb} Hadron Moments**
  - **Prospects for angle γ**



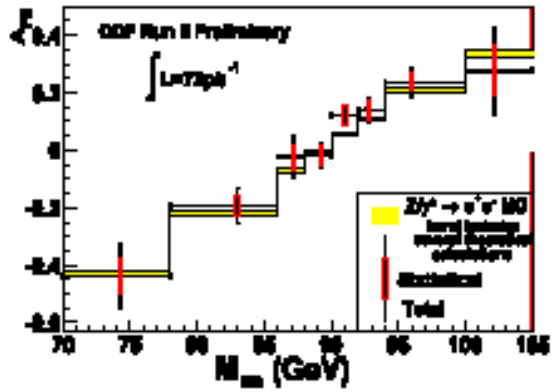


B mass

LBNL High P_T Physics in CDF

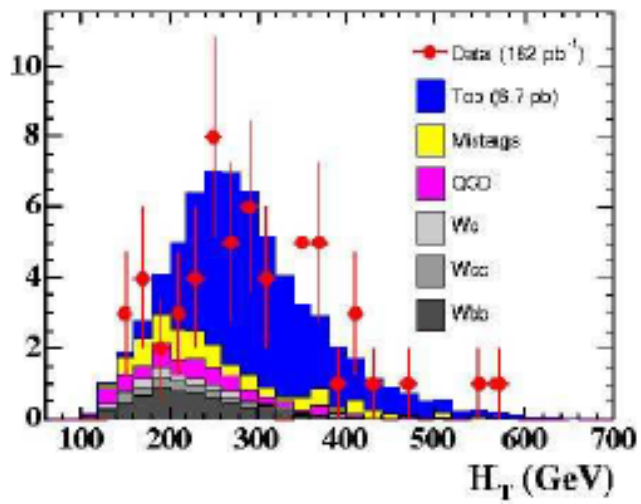
Electroweak + Top Physics

Z Asymmetry paper draft read by the collaboration
G. Veramendi (PHD thesis), A. Gibson

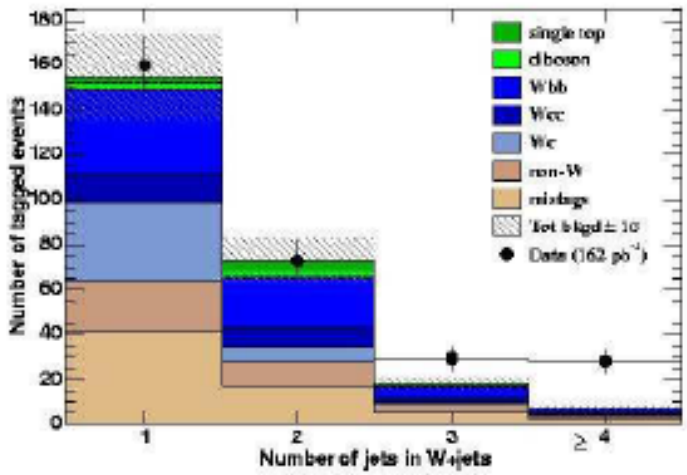


Top Cross Section using Silicon vertex tagging submitted to PRL
H. Bachacou (PHD thesis), J. Nielsen, W-M Yao

HT variable



Top signal in ⩾3 jets



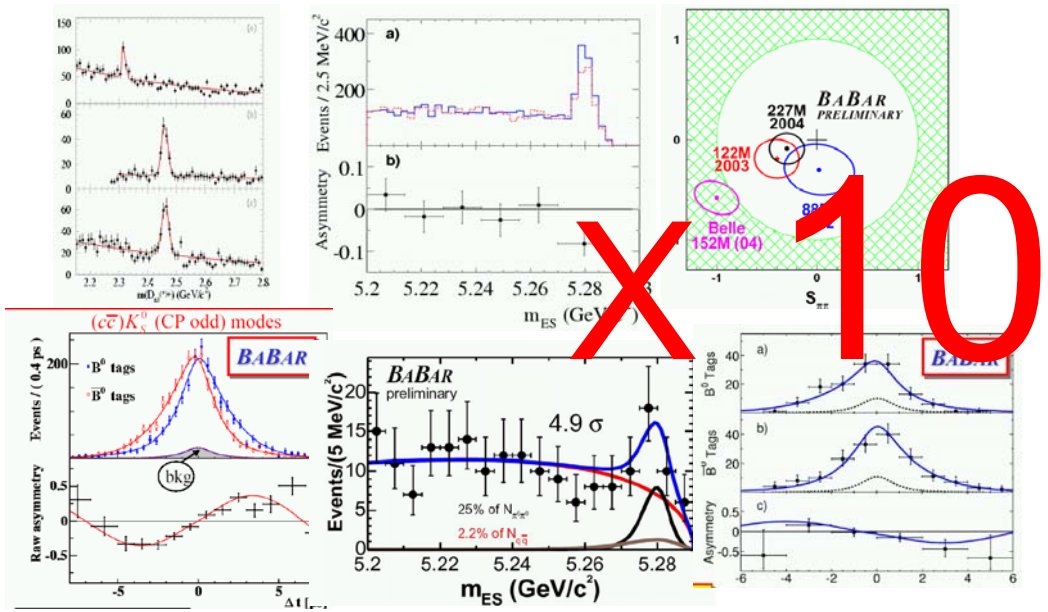
Major LBNL Contributions to BaBar Productivity

62 new BaBar results at ICHEP.

LBL-led new computing model (CM2) made much of this possible.

30 results used CM2.

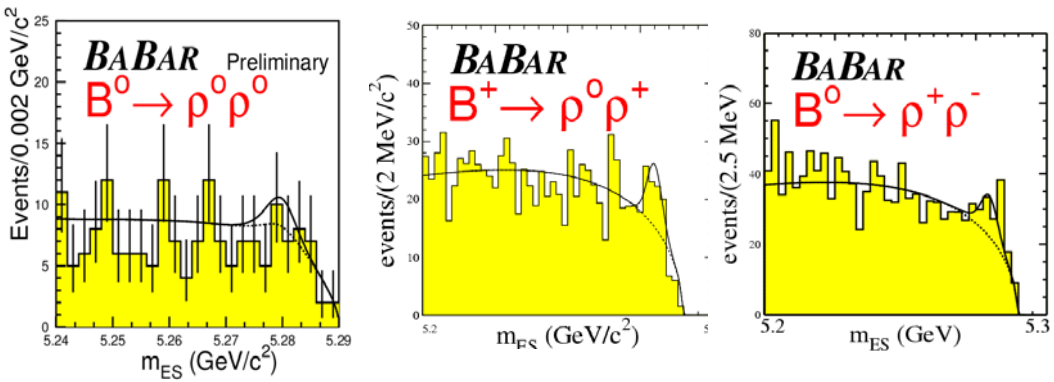
20 used data only 2 wks. old



LBNL: pioneers in B →VV

Improved limit on B→$\rho^0\rho^0$.

With $\rho^0\rho+$ and $\rho+\rho-$, this gives best measurement of α.



Major LBNL Contributions to BaBar Productivity

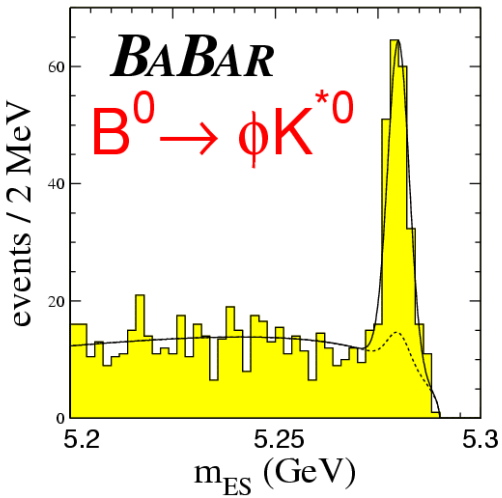
LBNL study of B → φK*

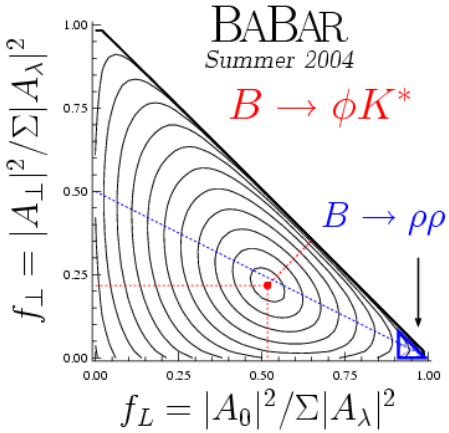
Full angular analysis.

CP tests.

Surprising polarization.

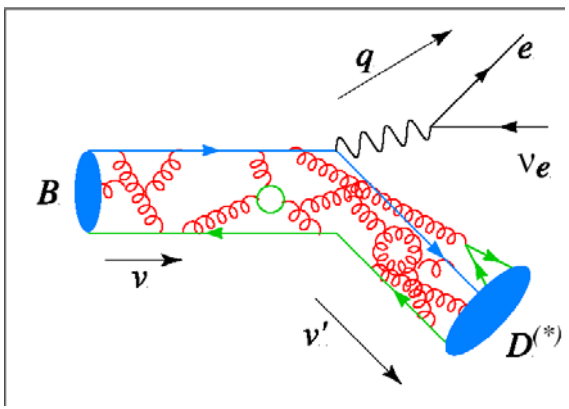
Strong phases measured.

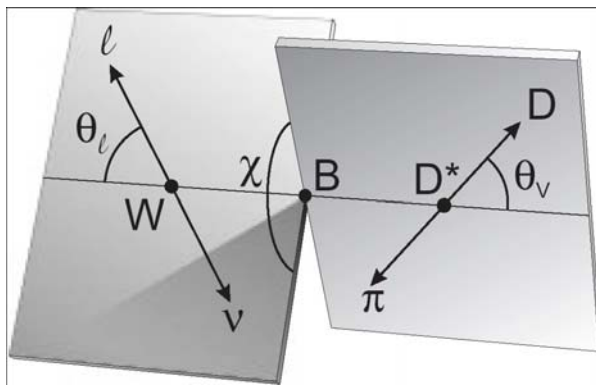




B →D*l ν

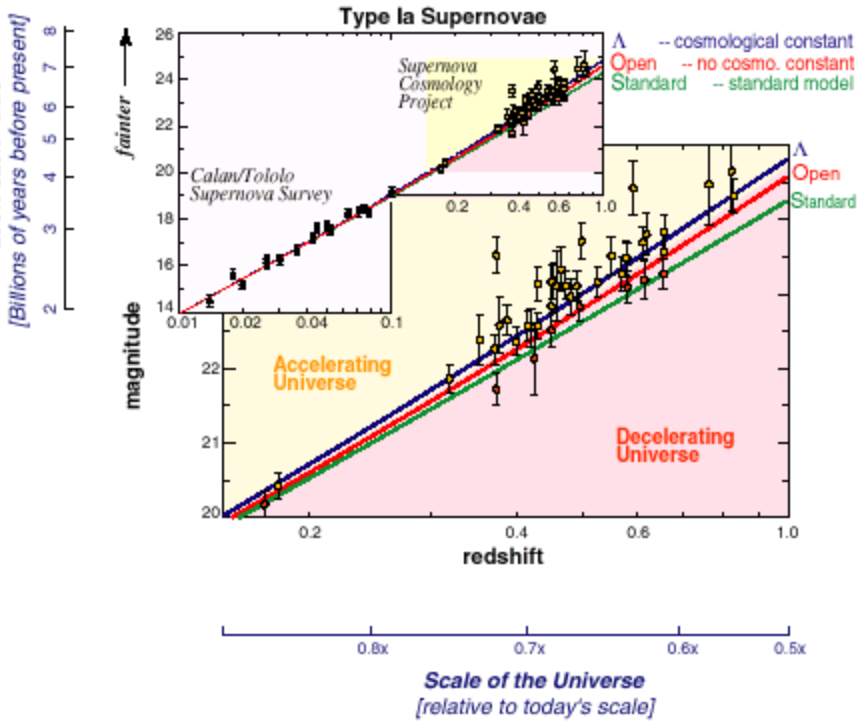
Best measurement by far of the form factors.





Pioneers in Supernova Cosmology

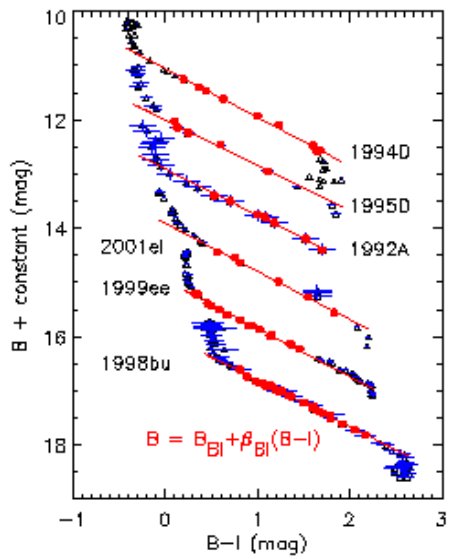
Supernova Cosmology Project



LBNL established the new field of distant supernova cosmology, discovered acceleration of universe.

New very distant supernova supports dark energy/cosmological constant interpretation.

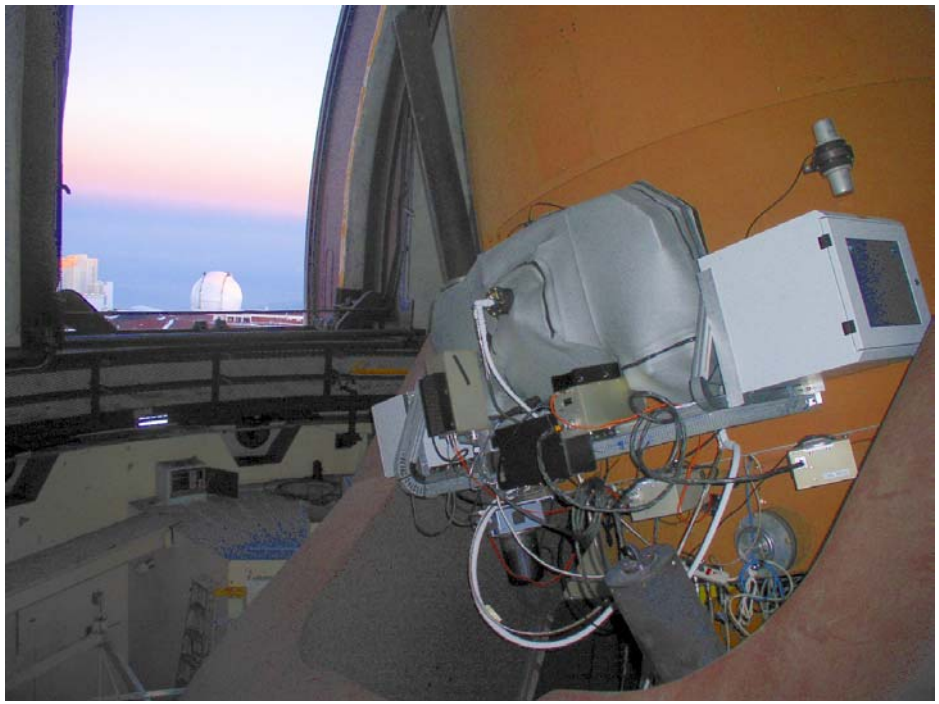
CMAGIC: Color Magnitude Intercept Calibrations



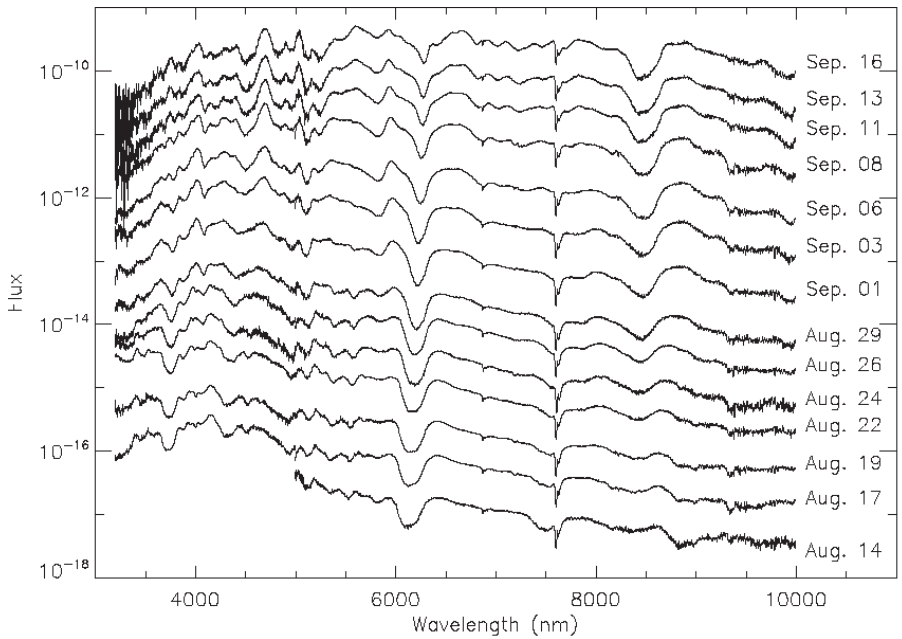
Next Steps: SN Factory – a nearby SN search

Continuing studies at Mid and Hi-Z

SuperNova Factory

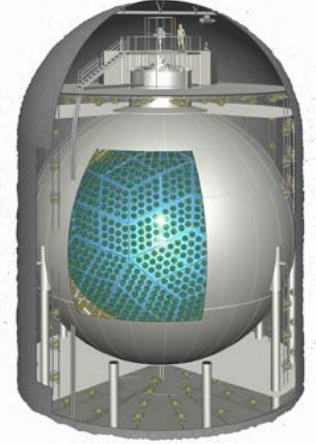


New Spectrograph (SNIFS) commissioned on the University of Hawaii 2.2m telescope w/ Keck and Subaru in background



SNIFS spectral time series of the Type Ia supernova SN 2004dt (with arbitrary offset; no absolute calibration)

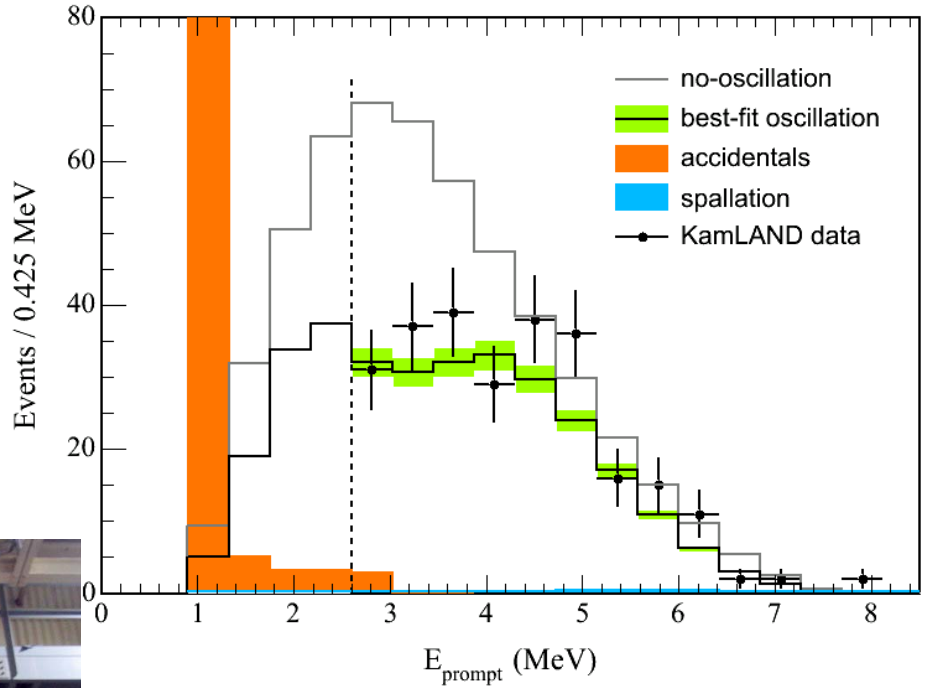
KamLAND in 2004



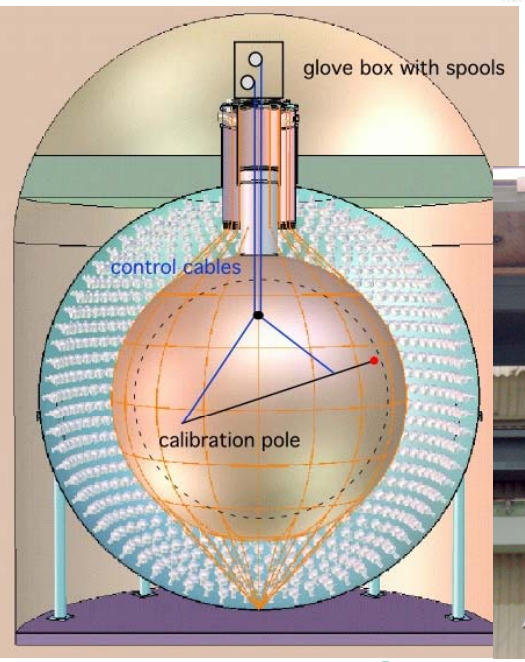
anti-neutrino measurement through inverse β-decay

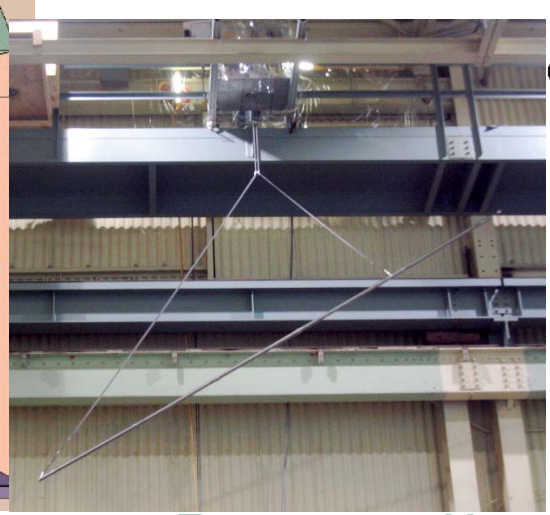
$$\bar{\nu}_e + p \rightarrow e^+ + n$$

Evidence of Spectral Distortion: Unique Signature of Neutrino Oscillation



hep-ex/0406035 (2004)





Calibration Systems Upgrade

Full-volume calibration for precision measurement of oscillation parameters.

Theory Group: progress in B physics

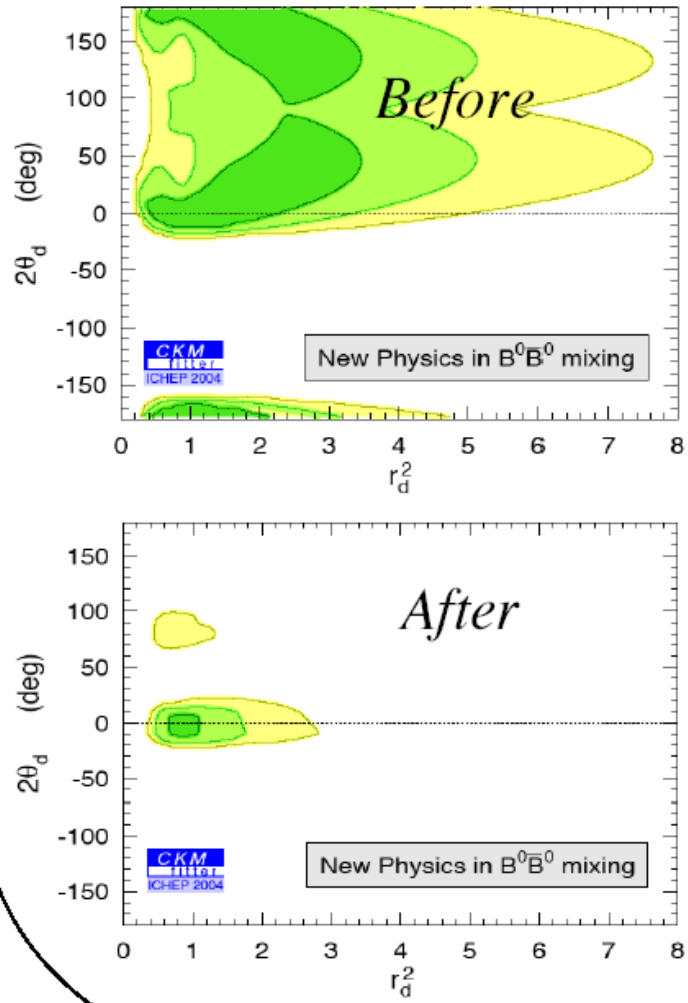
From ICHEP04-Beijing
Ligeti plenary talk,
The CKM matrix & CP Violation.

Initial measurements of CKM angles α and γ imply surprisingly strong constraint on new physics contribution to $B_0 - \overline{B}_0$ mixing, parameterized as

$$M_{12} = M_{12}^{(\mathrm{SM})} r_d^2 \, e^{2i\theta_d}$$

The CKM fit represents a huge effort by experimenters & theorists, many by Ligeti & collaborators, e.g.,

- V_{cb}, m_b – improved precision
- V_{ub}, γ – new measurement methods
- Theory of nonleptonic B decay



Theory Group Revitalization

New appointments for LBNL/UCB Theory Group

- UCB: 3 Asst. Prof. appointments in two years
- LBNL
  - Division Fellow search in progress
  - Second Div. Fellow search planned: ~ 07 - 08.

Joint LBNL/UCB agreement (including LDRD) ensuring support for LBNL Theory Group and for campus-based Center for Theoretical Physics.

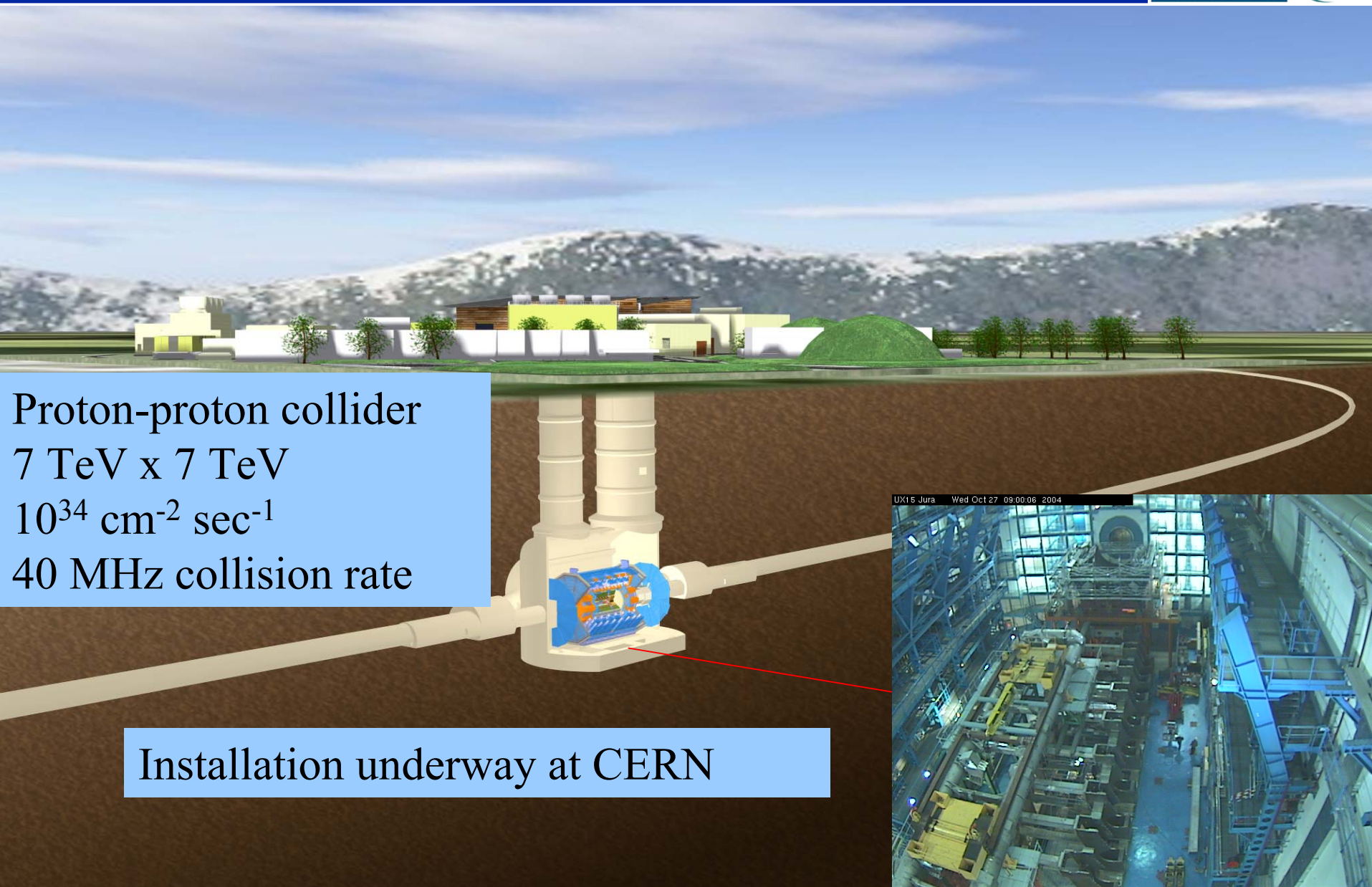
Facilities:

- UCB retrofit/renovation of "old Leconte"
- Projected renovation of LBNL theory facilities

Future Program:

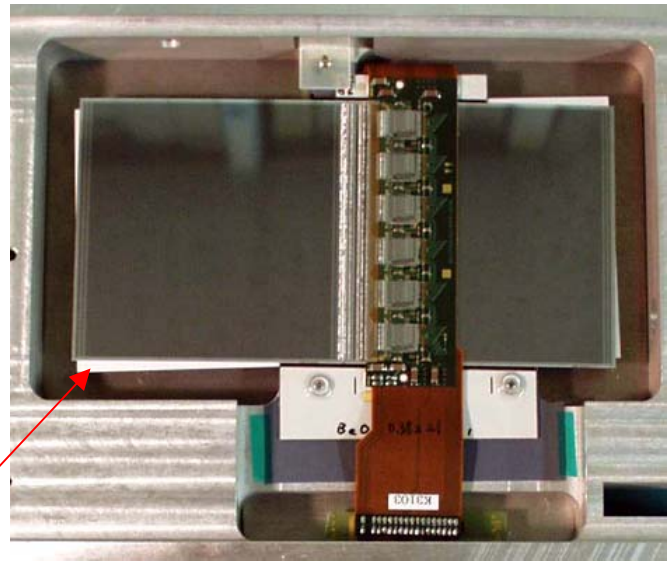
The Centerpieces

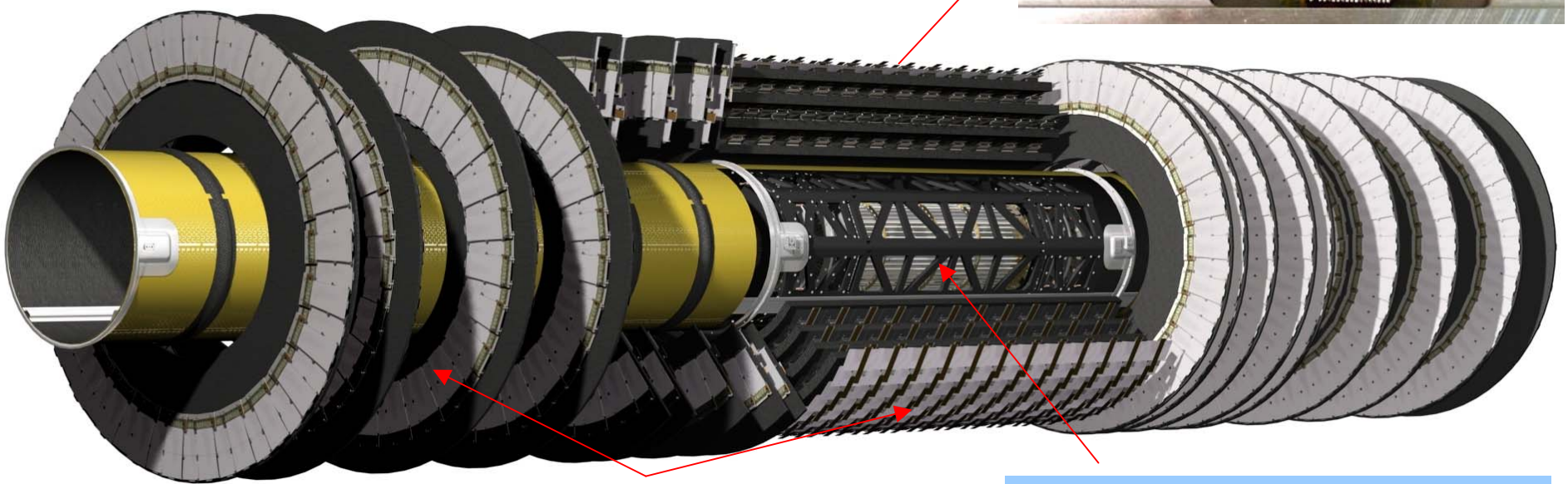
ATLAS at the Large Hadron Collider



ATLAS Silicon Tracking Detector

- **LBNL recently completed its part of the silicon strip tracking detector.**
- **Fabrication of the revolutionary silicon pixel detector will continue through 2005.**



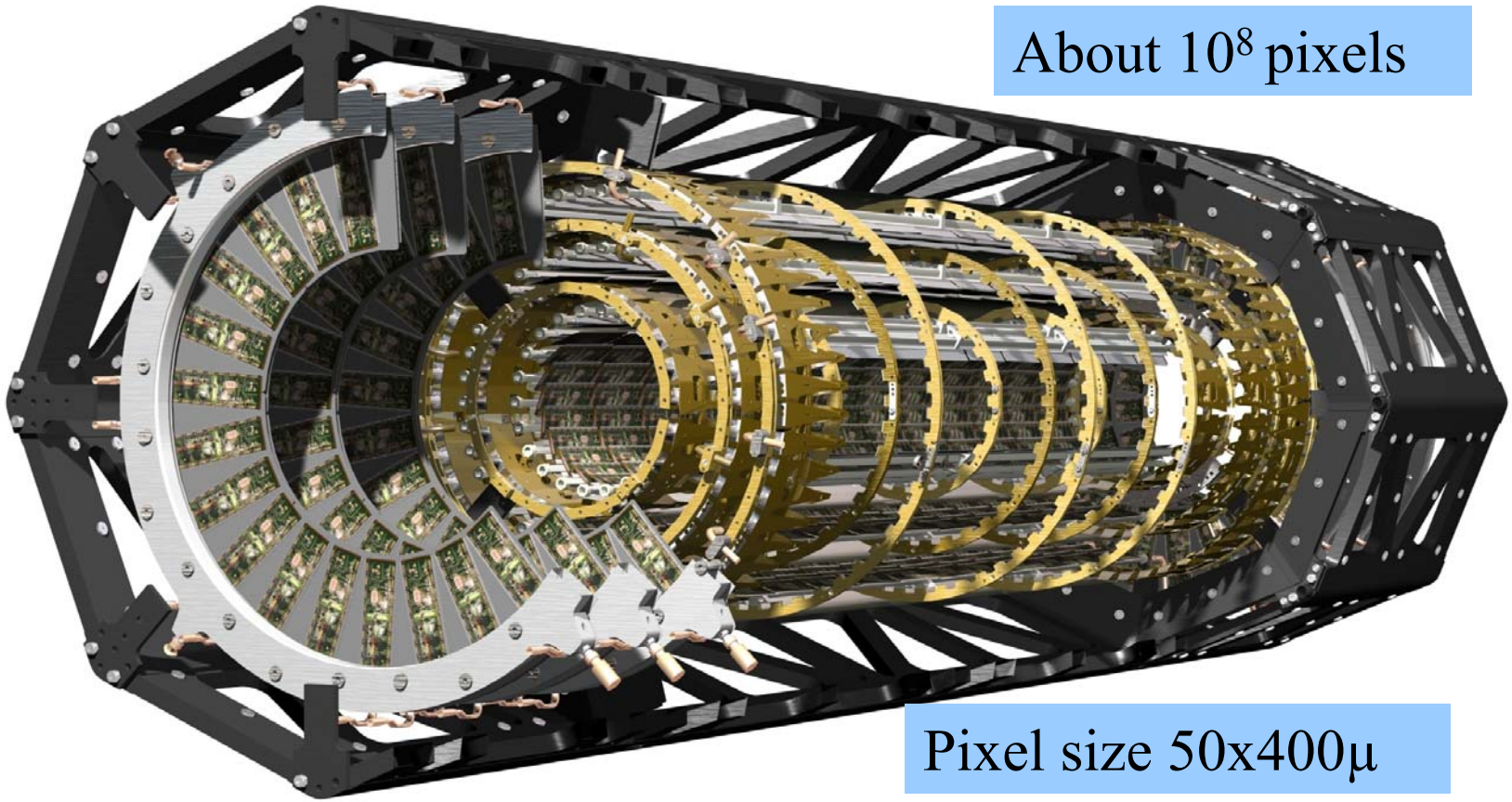


Silicon strip detector

Silicon pixel detector

Breakthrough Silicon Pixel Detector

- **<u>New technology</u> for hadron colliders, critical for LHC tracking, pioneered by LBNL.**
- **K. Einsweiler elected to be next Project Leader**



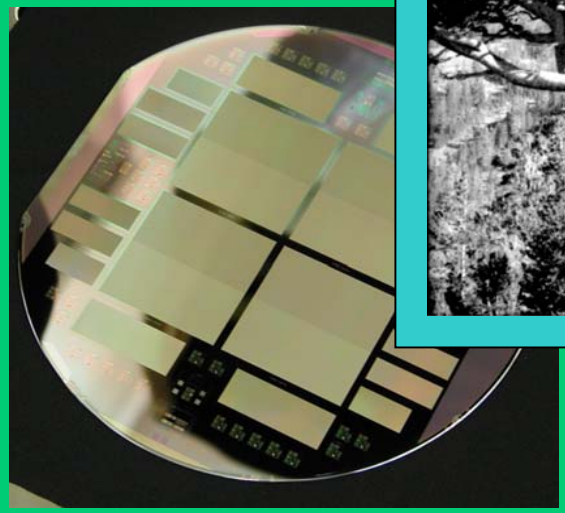
LBNL Leadership in ATLAS Physics,Software, Simulation

- Jacobsen submitted UC Berkeley Tier 2 computing proposal to NSF (partners with NERSC)
- Analysis of data from ATLAS will utilize computing resources and expertise from many countries around the world – the "Grid"
- NERSC staff at LBNL have a leading role in the critical software required to enable data reconstruction, analysis and simulation
- The overall Software Coordinator for ATLAS is D. Quarrie from LBNL
- I. Hinchliffe continues in leading role in Physics Coordination for ATLAS
- LBNL actively collaborating with ATLAS University groups in preparation for first Physics

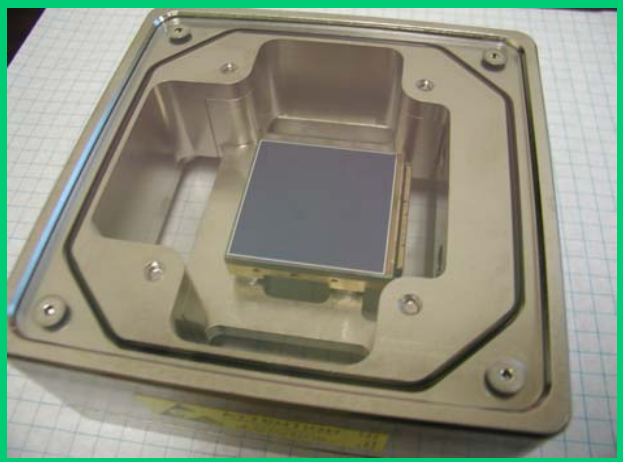
Joint Dark Energy Mission and SNAP

- High-level of SNAP R&D funding began in FY04
- Expecting flat level of funding through this fiscal year, FY05
- DOE continues to be very enthusiastic and supportive of JDEM and continues to push on NASA to establish a mission
- Major LBNL role in Science Definition Team
  - Levi
  - Perlmutter
  - Linder
- SNAP Collaboration continues to grow
- Successful SNAP collaboration meeting here last week

Optical

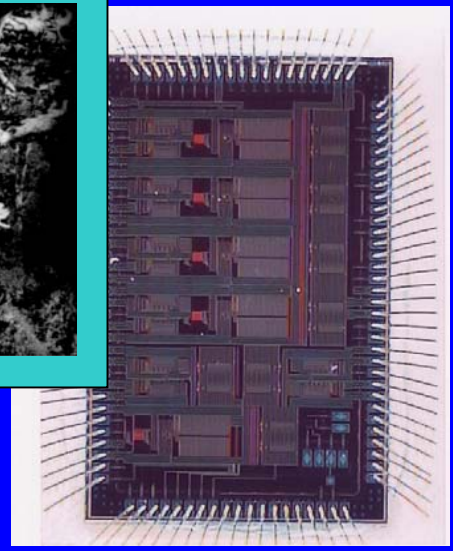


Current wafer with four SNAP CCDs – 3.5kx3.5k, 10.5 μm pixels.

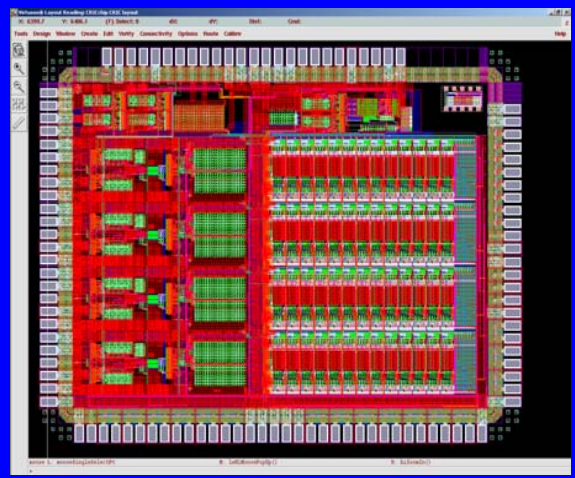


Rockwell 2k x 2k HyVisi

CCD electronics



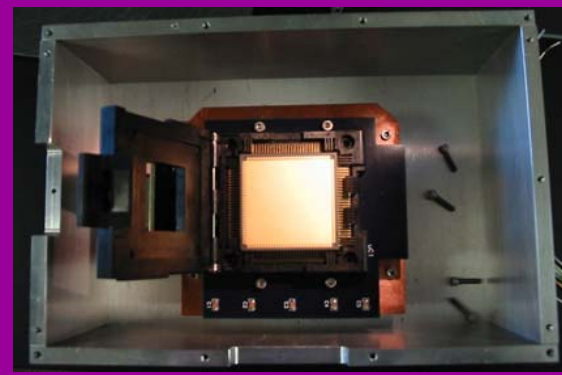
CRIC-I: Four channel dual integration correlated double sampler, operated at 140K.



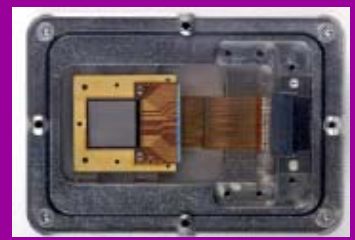
CRIC-II: with 13-b ADC

IR

Rockwell 2k x 2k, 1.7 um MCT.



Raytheon 1k x 1k, 1.7 um MCT



InGaAs 1k x 1k, 1.6 um looks like this.

Future:

In Development

Linear Collider

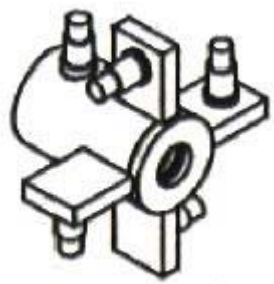
- **We expect to play a significant role in LC R&D as international program ramps up**
- **Battaglia, already a major contributor to LC program, beginning R&D program in silicon detectors**
- **Kolomensky active on beam instrumentation**
- **Ronan making major contributions to detector R&D, especially TPC**
- **Will collaborate with University groups on R&D**
- **Major LDRD support for instrumentation development**
- **LBNL bid to host the Global Design Initiative**

LC Beam Instrumentation at UC Berkeley

- Precision RF Beam Position Monitors for linac and beam delivery systems
  - — Resolution: nanometer-scale position resolution for single bunches, simultaneous measurement of beam position and tilt
    - Linac emittance control, IP feedback on ~300 nsec timescale (crucial for cold machine)
  - — Stability: 10^{-4} resolution *and* accuracy needed for beam energy measurements before IP
    - Requires ~100 nm stability over minute timescales
  - — Effort builds on E158 experience with RF BPMs
    - Faculty (Kolomensky), graduate student, two undergrads; supported by small grant through LCRD consortium
    - RF electronics, support for ongoing test beams (DAQ, data analysis)

➔ NanoBPM Collaboration (SLAC, KEK, LLNL, London, UCB)
  - — 70 nm single bunch resolution achieved this summer; hope to improve on that and demonstrate position stabilization

➔ BPM-based IP energy spectrometer for ILC (SLAC, London, Notre Dame, UCB)
  - — Prototype energy spectrometer at End Station A at SLAC
  - — Test beam time (tentative) in summer 2005 and 2006
  - — Aim to demonstrate required resolution and accuracy for TDR



Precision Measurement of θ_{13} with Reactor Neutrinos

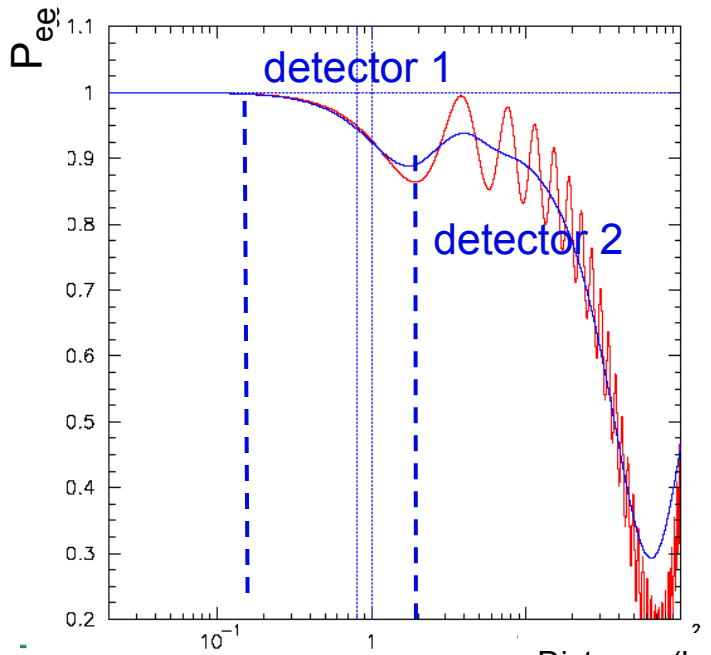
Search for U_{e3} in new oscillation experiment

Neutrinos

$$U_{MNSP} \sim \begin{pmatrix} 0.8 & 0.5 & U_{e3} \\ 0.4 & 0.6 & 0.7 \\ 0.4 & 0.6 & 0.7 \end{pmatrix}$$

APS Neutrino Study Recommends

- An expeditiously deployed multi-detector reactor experiment with sensitivity to $\overline{\nu}_e$ disappearance down to $\sin^2 2\theta_{13} = 0.01$, an order of magnitude below present limits.



→ Daya Bay offers opportunity for timely, precision θ_{13} experiment with horizontal access

→ LBNL/UCB formed R&D collaboration with IHEP, Caltech, BNL

CMB and Cosmology

- Integrated program combines effort at LBNL + UCB
- Strong program in theory, data analysis, algorithms
  - MAXIPOL, Planck
  - Collaboration with NERSC
- New instrumentation enables new experiments
  - APEX-SZ, South Pole Telescope
    - Galaxy Cluster Search - probe Dark Energy
  - POLARBEAR design ripe for construction
    - CMB Polarization - probe Energy Scale of Inflation
- LBNL leads readout development
- Significant funding through campus for joint program

Atacama Pathfinder Experiment (APEX-SZ)

- **16,500 feet in Chilean Andes.**
- **12m on-axis ALMA prototype**

Berkeley SZ Receiver:

- **330 Bolometer array**
- **Discover 4000 Clusters/2yrs**
  - **Mass limit > 4×10^{14} M_0**
- **First Light *Spring 2005*.**
- **LBNL responsible for readout**

UC Berkeley/LBNL, MPI-Bonn/Munich, Cardiff

Galaxy Cluster Search - probe Dark Energy

Future:

- **South Pole Telescope readout**
- **POLARBEAR (B mode polarization)**

Community Service, Education & Outreach

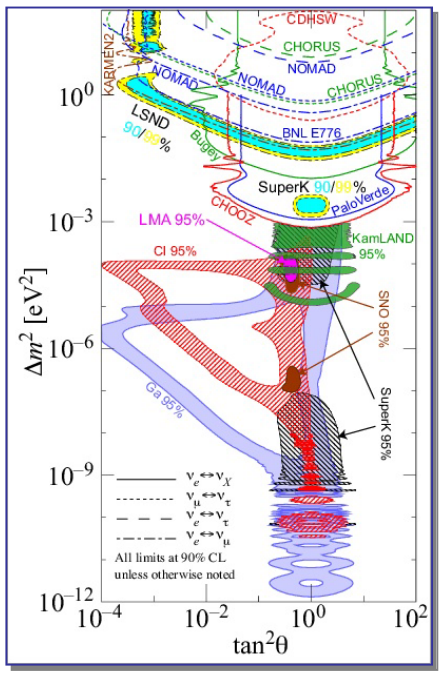
Service to the Community

Barnett	Vice-Chair, APS Calif. Sec.
	VP AAPT No. Calif. Sec.
	Chair, ATLAS Outreach
Murayama	FNAL PAC
	DPF Executive Committee
Roe	FNAL PAC
	DESY Scientific Council
	Vice Chair, DPF
Cahn	HEPAP (pending)
Siegrist	DESY Helmholtz Review Committee
Perlmutter	HEPAP (pending), JDEM Science Definition Team
Oddone	MUCOG, LHC oversight
Carithers	Chair, DPF
Levi	JDEM Science Definition Team
Linder	JDEM Science Definition Team

Particle Data Group

- Review of Particle Physics
- Census/Survey Activities
- Education/Outreach Programs

Leading a Collaboration of 156 authors from 17 countries (90 institutions) + 700 contributors.



RPP has 500 new papers, 1700 new measurements, 119 reviews.

28,000 Booklets, 13,000 RPP books, website: 5-10 million hits/yr.

According to SLAC Library, RPP is the all-time top cited article in HEP with 19,775 citations (2nd is Weinberg's SM paper with 5424).

- Improved coverage though vital PDG workshops: Neutrino, CKM, and Extra-dimensions Workshops
- Growing coverage of Astrophysics and Cosmology

Education and Outreach

Involving Students, Teachers & the Public

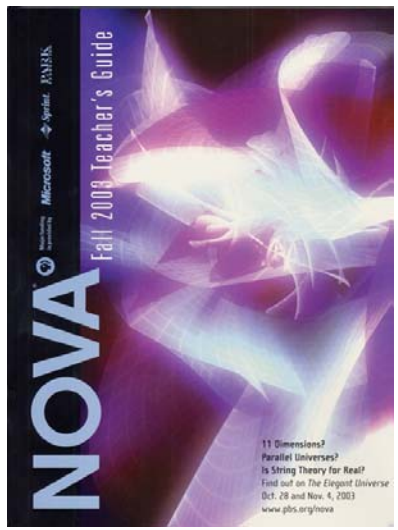
QuarkNet sites

QuarkNet – Co-Founder and Co-PI

Centers at 54 universities, 11 different HEP experiments, 500 high schools in 37 states. Impacts on 60,000 students/yr.

Changing teachers and teaching by making them part of of research collaborations.

Collaboration with NOVA on "Brian Greene's Elegant Universe"



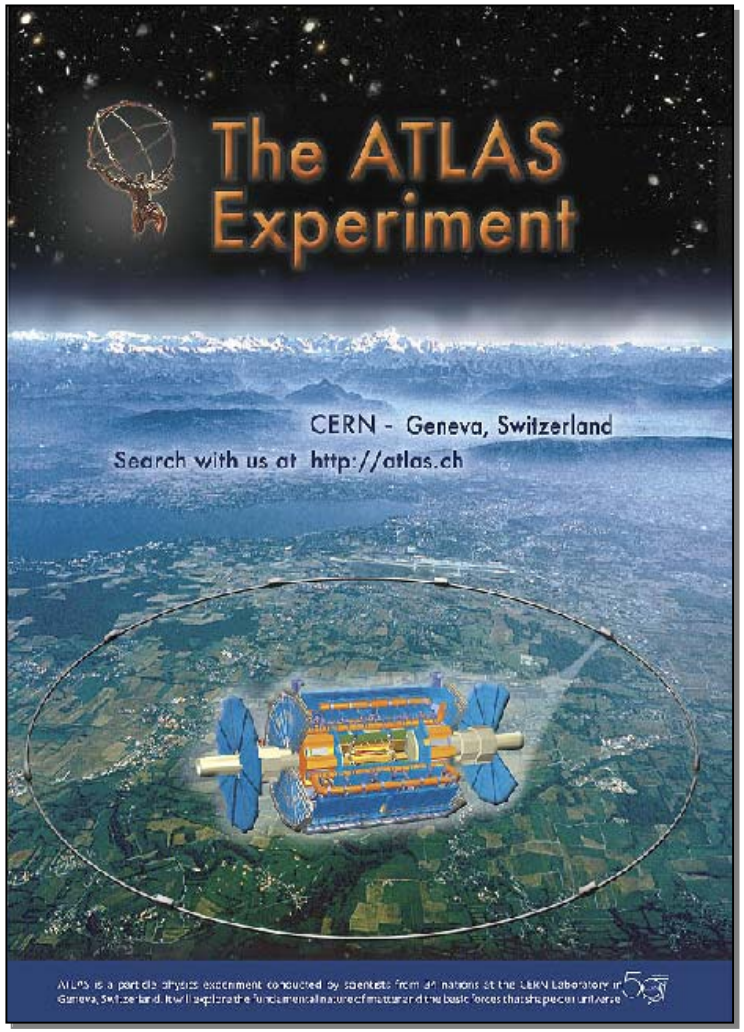
The Particle Adventure

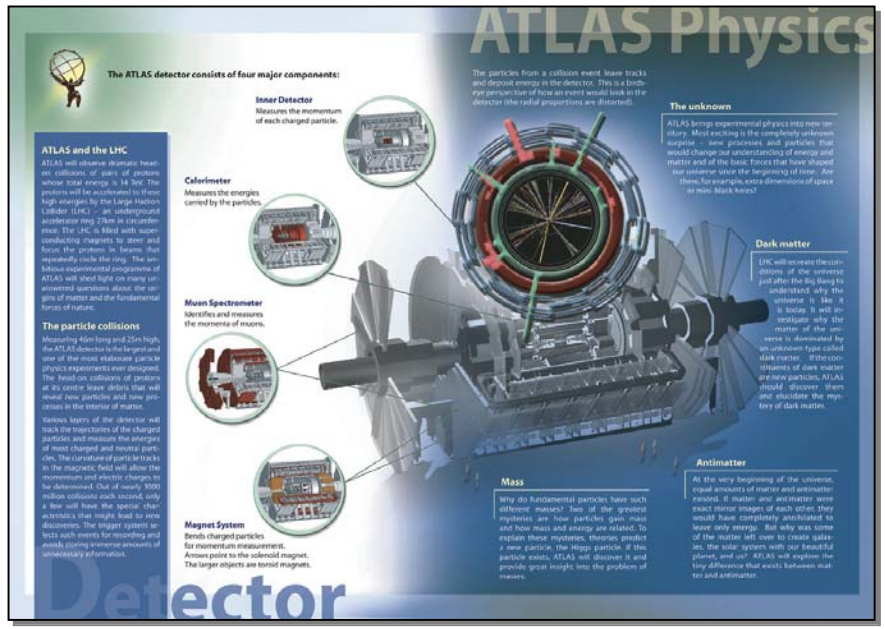
Languages: Spanish, French, Polish, Finnish, Chinese, Italian, Portuguese, Slovak, Greek, German, Norwegian, Dutch.

Featured by: Scientific American, Discovery Channel, USA Today, Education World, DOE's KidzZone,

ATLAS Reaches Out

New Brochure





Funding and Division-wide Issues

Budgetary Outlook

- **Significant increase FY03 to FY04 to support SNAP R&D but some was at the expense of other parts of our program (~10% reduction)**
- **Increased scope-of-work has strained our resources significantly**
- **In order to support hiring new staff into high-priority programs we have reduced staff elsewhere**
- **We are reducing research efforts across the division to match funding**

LDRD Support for Physics

Title	PI	1999	2000	**2001**	**2002**	**2003**	2004	2005
								(10/04)
Large Astrophysical Data Sets	Smoot	84,500	75,000	**80,000**	—	—	—	—
Foundations for a SuperNova/Acceleration Probe (SNAP)	Levi/Perlmutter	x	628,800	**599,800**	**1,199,700**	—	—	—
Modeling of High Energy Physics Detectors	Hinchliffe	x	x	**90,300**	**94,600**	**99,800**	—	—
POLARBEAR: An Experiment to Measure Polarization Anisotropy in the CMB	Lee	x	x	**100,100**	**101,400**	**100,100**	—	—
Future Experiments in Neutrino Physics	Freedman	x	x	**x**	—	**47,000**	64,000	—
New Projects								
Designing a Novel Reactor Neutrino Oscillation Experiment for Measuring the Unknown Mixing Angle Q13	Heeger et al	x	x	x	—	—	263,300	300,000
Silicon Detectors for a Linear Collider	Battaglia	x	x	x	—	—	—	180,000
New Directions for Theoretical Physics at the TeV-Scale	Murayama	x	x	x	—	—	—	250,000

Areas for Advice

- Advise Steve Chu on the quality and impact of our work
- Advise us how to improve making our science case to the community
  - — we are seeking support from our collaborations
  - — ongoing physics at LBNL squeezed dramatically…
- How do we make the case to the lab for further investment in the Division in the post-SNAP LDRD era?
  - — Neutrinos
  - — Astrophysics development, theory and experiment
  - — New instrumentation for future experiments and other fields
- How do we make a better enterprise with the support we have now?
- What opportunities are we missing? What are we “not seeing”?

Summary

- **Present program is producing great physics; need ongoing support**
- **Future program is very exciting, technical progress is excellent**
- **New ideas are very attractive**

LBNL is a center of excellence that serves the HEP community well

Prospects

We look forward to great physics!

- *CP violation*
- *Higgs*
- *SUSY*
- *Dark energy*
- *Extra dimensions and even more*